THE EVOLUTION OF CLIMATE IN NORTH-WESTERN EUROPE: A REVIEW*

By ELLSWORTH HUNTINGTON

Yale University

During the last few years Mr. C. E. P. Brooks has published a number of important papers on changes of climate. In the article under review he gives an admirable summary of the main climatic pulsations from the height of the glacial period to the time of Christ. His climatic table, based on his article in the annual report of the Smithsonian Institution for 1917,[1] is as follows:

PHASE	CLIMATE	DATE
1. Last Great Glaciation	Arctic	30,000–18,000 B.C.
2. Retreat of the Glaciers	Severe continental	18,000–6000 B.C.
3. Continental	Continental	6000–4000 B.C.
4. Maritime	Warm and moist	4000–3000 B.C.
5. Later Forest	Warm and dry	3000–1800 B.C.
6. Peat-Bog	Cooler and moister	1800 B.C.–300 A.D.
7. Recent	Becoming drier	300 A.D.—

This table needs amplification. Mr. Brooks bases his chronology largely on Gerard De Geer's measurements of the annual layers of clay in lake bottoms but makes much use of other evidence. According to Brooks, the last glacial epoch lasted roughly from 30,000 to 18,000 B.C.; but this includes a slight amelioration of climate followed by a readvance of the ice, known as the Buhl stage. During the time of maximum glaciation the British Isles stood twenty or thirty feet higher than now, and Scandinavia was "considerably" more elevated. The author believes that this caused a fall of 1° C. in the temperature of the British Isles and of 2° C. in Scandinavia. By an ingenious though not wholly convincing method of calculation, which is explained in previous publications, the author concludes that this increase of temperature aided by an increase in the area of the lands sufficed to start an ice sheet in Scandinavia. The ice area, though relatively small in extent, cooled the air and gave rise to an area of high barometric pressure. This in turn is supposed to have caused further expansion of the ice and thus to have led to full-fledged glaciation.

About 18,000 B.C. the retreat of the ice began in good earnest. Even though no evidence has yet been found, Brooks believes there must have

* C. E. P. Brooks: The Evolution of Climate in North-West Europe, *Quart. Journ. Royal Meteorol. Soc.*, No. 199, Vol. 47, 1921, pp. 173–194, London.

[1] C. E. P. Brooks: The Correlation of the Quaternary Deposits of the British Isles with those of the Continent of Europe, *Ann. Rept. Smithsonian Instn.* for 1917, pp. 277–375.

been some change in the distribution of land and sea to account for the diminution of the ice. The ensuing millenniums formed the Magdalenian period in human history, the last stage of the Paleolithic, when man lived in caves and reindeer were abundant in central Europe.

The Retreat of the Glaciers

At first the ice retreated very slowly, and there were periods when for scores of years the ice edge remained stationary or even readvanced. About 10,000 B.C. the edge of the ice lay along the southern coast of Sweden. During the next 2,000 years it withdrew more rapidly to about 59° N. Then came the Fennoscandian pause, or Gschnitz stage, when for about 200 years the ice edge remained in one position, forming a great moraine. Brooks suggests that this pause, about 8000 B.C., was due to the closing of the connection between the Atlantic Ocean and the Baltic Sea and the synchronous opening of a connection between the Baltic and the White Seas, whereby cold Arctic waters replaced the warmer Atlantic waters. He notes, however, that about 7500 B.C. the obliquity of the ecliptic was probably nearly 1° greater than at present. This he calculates to have caused the climate of Germany and Sweden to be 1° F. colder than at present in winter and 1° F. warmer in summer.

The Continental Phase

The next climatic stage was marked by a rise of temperature till about 6000 B.C. During this period the ice at first retreated, presumably because the climate was ameliorating, although no cause of such amelioration is assigned. At length the ice lay far enough north to allow a connection between the Baltic and the Atlantic by way of Lakes Venern and Vettern in southern Sweden. This is supposed to have warmed the Baltic Sea and caused the climate to become distinctly milder. Next the land rose once more so that the Baltic was separated from the Atlantic and was converted into the Ancylus lake of fresh water. The southwestern Baltic region then stood 400 feet higher than now. The result was the Daun stage, about 5000 B.C., when the ice halted or perhaps readvanced a little, its front being then near Ragunda in about latitude 63°. Why such an elevation did not cause renewed glaciation, instead of merely the slight Daun pause, Brooks does not explain, although his calculations as to the effect of a slight elevation of the land during the main period of glaciation from 30,000 to 18,000 B.C. would seem to demand a marked readvance.

After 5000 B.C. there ensued a period when the climate, although still distinctly continental, was relatively mild. The winters, to be sure, were still cold, but the summers were increasingly warm. In Sweden, for example, the types of vegetation indicate that the summer temperature was 7° F. higher than now. Storms were comparatively rare except on the outer fringe of the British Isles. There they were sufficiently abundant so that in the

northwestern part of the islands they gave rise to the first Peat-Bog period, during which swamps replaced forests of birch and pine. Southern and eastern England, however, probably had a dry continental climate. Even in northwestern Norway storms were rare, as is indicated by remains of forests on islands now barren because of the strong winds and fierce storms. Further east most parts of central and northern Europe were relatively dry. This was the Early Neolithic period when man advanced from the use of unpolished to polished stone implements.

The Maritime Phase

Not far from 4000 B.C. the period of continental climate was replaced by a comparatively moist maritime climate. Brooks believes that this was because submergence opened the mouth of the Baltic and caused the fresh Ancylus lake to give place to the so-called Litorina sea. The temperature in Sweden averaged about 3° F. higher than at present, and in southwestern Norway 2°. More important than this was the small annual range of temperature, due to the fact that the summers were cool while the winters were mild. Because of the presence of a large body of water in the Baltic region, storms, as our author states, then crossed the British Isles and followed the Baltic depression, carrying the moisture far inland. In spite of the additional moisture thus available the snow line in southern Norway was higher than now.

At this point Brooks turns to other parts of the world. He states that not far from 4000 B.C. a submergence of the lands, rarely amounting to more than 25 feet, took place not only in the Baltic region but in Ireland, Iceland, Spitsbergen, and other parts of the Arctic Ocean, as well as in the White Sea, Greenland, and the eastern part of North America. Evidences of a mild climate are found in all those places. Similar evidence of a mild, warm climate is found in eastern Africa, eastern Australia, Tierra del Fuego, and Antarctica. The dates are not established with certainty, but they at least fall in the period immediately preceding the present epoch. In explanations of these conditions Brooks assumes a universal change of sea level. He suggests with some hesitation that this may have been due to one of O. Pettersson's periods of maximum "tide-generating force." According to Pettersson the varying positions of the moon, earth, and sun cause the tides to vary in cycles of about 9, 90, and 1,800 years, though the length of the periods is not constant. When tides are high there is great movement of ocean waters and hence a great mixture of the water in different latitudes. This is supposed to cause the amelioration of climate. The periods of maximum and minimum tide-generating force are as follows:

Maxima	3500 B.C.	2100 B.C.	350 B.C.	1434 A.D.
Minima	2800 B.C.	1200 B.C.	530 A.D.	

Brooks thinks that the big trees in California and the Norse sagas and Germanic myths indicate a rough agreement of climatic phenomena with

Pettersson's last three dates, while the mild climate of 4000 B.C. may really belong to 3500 B.C. He gives no evidence confirming Pettersson's view of the other three dates.

The Later Forest Phase

To return to our sketch of climatic pulsations, by 3000 B.C., that is toward the close of the Neolithic period, further elevation had taken place over the central latitudes of western Europe. Southern Britain, which had remained constantly above its present level ever since 30,000 B.C., was 90 feet higher than now. Ireland was somewhat enlarged by elevation, the Strait of Dover was almost closed, and parts of the North Sea were land. To these conditions Brooks ascribes the prevalence of a dry continental climate. The storms shifted northward once more, the winds were mild, as seems to be proved by remains of trees in exposed places, and forests replaced fields of peat and heath in Britain and Germany. The summers were perhaps warmer than now, but the winters were severe. The relatively dry climate prevailed as far west as Ireland. For example, in Drumkelin Bog in Donegal County a corded oak road and a two-story log cabin appear to belong to this time. Fourteen feet of bog lie below the floor and 26 above. This period, perhaps 3000–2000 B.C., was the legendary heroic age of Ireland when "the vigour of the Irish reached a level never since attained." This, as Brooks points out, may have been a result of the relatively dry climate, for today the extreme moisture of Ireland seems to be a distinct handicap. In Scandinavia civilization, or at least the stage of relative progress, was also high at this time.

The Peat-Bog Phase

By 1600 B.C. the land had been submerged to its present level in the British Isles and the southern Baltic region, while northern Scandinavia still stood lower than now. The climate of Britain and Germany was so humid that there was an extensive formation of peat even on high ground not before covered. This moist stage seems to have lasted almost to the time of Christ and may have been the reason why the Romans describe Britain as peculiarly wet and damp. At this point Brooks again departs from northwestern Europe to a wider field:

> It is possible that we have to attribute this damp period in North-West Europe to some more general cause, for Ellsworth Huntington's curves of tree-growth in California and climate in Western Asia both show moister conditions from about 1000 B.C. to A.D. 200, and the same author believes that the Mediterranean lands had a heavier rainfall about 500 B.C. to A.D. 200. It seems that the phase was marked by a general increase of the storminess of the temperate regions of the northern hemisphere at least, with a maximum between Ireland and North Germany, indicating probably that the Baltic again became the favourite track of depressions from the Atlantic.

Postglacial Changes in North America

Mr. Brooks ends his paper with a brief résumé of postglacial changes in North America; but, as the means of dating events are unreliable, the degree

of synchronism with Europe is not clear. He sums up his conclusions as follows:

> On the whole it appears that though there is a general similarity in the climatic history of the two sides of the North Atlantic, the changes are not really contemporaneous, and such relationship as appears is due mainly to the natural similarity in the geographical history of two regions both recovering from an Ice Age, and only very partially to world-wide pulsations of climate. Additional evidence on this head will be available when Baron de Geer publishes the results of his recent investigations of the seasonal glacial clays of North America, especially if, as he hopes, he is able to correlate the banding of these clays with the growth-rings of the big trees.
>
> When we turn to the north-west of North America, this is brought out very markedly. For in Yukon and Alaska the Ice Age was a very mild affair compared with its severity in eastern America and Scandinavia. As the land had not a heavy ice-load to recover from, there were no complicated geographical changes. Also, there were no fluctuations of climate, but simply a gradual passage to present conditions. The latter circumstance especially seems to show that the emphasis laid on geographical rather than astronomical factors of *great* climatic changes is not misplaced.

Mr. Brooks's painstaking discussion of postglacial climatic changes is of great value because of the large body of material which he has so carefully wrought together. His strong belief in the importance of changes in the level of the lands deserves serious consideration. It is difficult, however, to accept his final conclusion that such changes are the main factors in *great* climatic changes. It is almost impossible, for example, to believe that movements of the land could produce almost the same series of climatic changes in Europe, Central Asia, the western and eastern parts of North America, and the southern hemisphere. Yet that is what appears to have happened during and since the glacial period. Again, there is no evidence whatever that movements of the land have anything to do with the historic cycles of climate or with the cycles of weather in our own day, which seem to be the same as climatic cycles on a small scale. Also, as Dr. G. C. Simpson points out in the discussion of Mr. Brooks's paper before the Royal Meteorological Society, there appears "no solution along these lines of the problem connected with rich vegetation in both polar circles and the ice-age which produced the ice-sheet at sea-level in Northern India." We may well believe that Mr. Brooks is right in holding that changes in the relative level and relative area of land and sea have had important local effects. His appeal to astronomical causes is not really a sign of weakness in his own theory, as was suggested in the discussion. It is merely a sign that so complicated a natural phenomenon as climatic changes cannot be explained by any one theory. While changes in the level of the lands may not be the main cause, they are certainly a contributory cause which cannot be neglected.